17.2 b

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE-RESEARCH
WASHINGTON 25, D.C.

In cooperation with the
Illinois Agricultural Experiment Station

SOIL WATER AND ITS DISPOSAL UNDER CORN AND BLUEGRASS

By
H. N. Holtan
and
G. W. Musgrave

SCS-TP-68
July 1947

CONTENTS

TABLES

FIGURES

FIGURES (Cont'd)

SUMMARY

A study was made of the movement of water within the soil profile as affected by or related to infiltration, consumptive use of water by grass, by corn, and by soils of high and moderate permeability. The period covered was a portion of two successive years having above-average rainfall. The results are to be considered, therefore more as a pilot study than as conclusive findings. Of particular interest, however, were certain results believed to be of general applicability.

1. More water was used by grass than by corn under like soil and climatic conditions.

2. More water was available for movement to depths below root zone in areas growing corn than those growing grass.

3. The amount of water moving below root zone was governed more by the comparative amounts used by the two contrasting types of vegetation than it was by either the amount of infiltration or by soil permeability.

The findings came from small triplicated watersheds on Berwick and Tama silt loams. Probably the magnitudes of infiltration, consumptive use, and water moving below root zones would be different under other climatic conditions, but it may well be that the comparative results from the dense and sparse vegetal cover would be in the same direction as reported herein.

SOIL WATER AND ITS DISPOSAL UNDER CORN AND BLUEGRASS

By H. N. Holtan, agricultural engineer, and G. W. Musgrave, research specialist, Research Soil Conservation Service

THE PROBLEM AND OBJECTIVES OF THE STUDY

There is very little direct evidence in the literature on the relationship between rainfall, infiltration, and movement of water to depths below root zone. Despite the fact that it is recognized that ground water has its source in the infiltration of precipitation in many instances, nevertheless we do not have much evidence as to the specific effects of different land uses on the downward movement of water.

Ground-water levels have been shown by numerous workers to be gradually declining so that the depletion of this source of water has been sufficient to be a matter of concern to many groups of people. Many manufacturers are dependent upon supplies of clear, cool water particularly for such processes as the distillation of alcohol. Many municipalities and steam plants are dependent upon ground-water supplies for proper operation. There are large areas of irrigated lands that are dependent upon this water as their source of supply. When depletion proceeds at a high rate, the situation naturally becomes one of real concern to these groups of people who are dependent upon ground water. In a broader sense, the situation is a matter of concern to the entire Nation, in the same manner that the exhaustion of various minerals or other natural resources is properly the concern of the Nation.

Ordinarily the affected aquifers generally underlie agricultural areas. On many such areas extensive programs are under way to reduce surface runoff and increase infiltration. In an area where ground-water depletion has occurred, to what extent are conditions at the ground surface a controlling factor? Are they such that a considerable portion of the rainfall is prevented from entering the soil? Are such conditions limited to certain local areas above the aquifer or are they widespread? Where intake of water at the surface is limited by soil condition, is it possible to improve the soil structure effectively and practically? If improved so that there is a large increase in the intake of precipitation, what part of the increase will go to the water table, what part to perched effluent or to base flow of streams, and what part to the vegetation growing above it?

These are some of the questions that need to be answered in any complete analysis of a situation where it is believed the rate of depletion may be alleviated by improved land use. Even though the answers to these questions may not provide a complete solution to the problem of alleviating the ground-water shortage they may indicate ways by which such depletion may be reduced. The problem involves the relative importance of rainfall, infiltration, and consumptive use of water by plants in relation to potential accretions to ground water.

The study reported herein was confined to a 2-year period and was designed as an exploration of the problem of disposition of water in the root zone and adjacent portion of the soil profile. It is in no sense a completed investigation. It does indicate some of the kinds of information that are necessary if a full understanding of the problem and of the interrelationships of the different demands for water consumption are fully understood.

THE GENERAL PLAN OF STUDY

The general plan of study comprised two separate phases or stages. In the first phase, an infiltrometer survey was made of dominant land usages above an aquifer that was known to have been depleted at an accelerated rate. This survey of the rates of infiltration for

the dominant land usages on two of the dominant soils of the area is described in detail subsequently. Its purpose was to ascertain whether or not appreciable differences in infiltration existed on the lands above the aquifer and to what extent such differences, if found, bore a relation to land use or to soil characteristics.

The second phase of the study included investigations upon small watersheds that were representative of the uses and soils that were included in the first phase. In these studies an attempt was made to determine under natural field conditions the interrelationships between rainfall, runoff, infiltration, soil moisture accretion and depletion, the consumptive use of water by the crops, and the amount of water moving below root zone and which potentially might become available for ground-water accretion. In this phase of the study, triplicate watersheds with two dominant land uses common to the region and on two dominant soils were established and measurements continued for a period of approximately 2 years. It so happened that the 2 years included in the investigations had abnormally high rainfall during the spring months. The results therefore must be regarded as indicative of those which may occur under the conditions prevailing and not necessarily those that would occur in dry years or perhaps even in average years.

PROCEDURES EMPLOYED

Infiltrometer Survey

In the infiltrometer survey the two dominant soils and the two dominant crops of six townships in Peoria County., Ill., were samples (fig. 1, p. 3). This area lies above the supposed location of an aquifer being rapidly depleted.

According to the census, the two dominant crops at the time this work was started were corn and bluegrass, which were of approximately equal extent and occupied about 60 percent of the area. The soil surveys show that the two dominant soils are the Tama and the Berwick silt loams. Each occupies about one-fourth of the area and together include one-half of it. The former is a prairie soil known to be relatively permeable. The latter is a timber soil having a gray layer about a foot below the surface and reputedly is much less permeable.

The survey in 1942 included seven pairs of sites on the Tama silt loam and a like number on the Berwick silt loam. One member of each pair was in bluegrass and one in corn. The work was so planned that both members of each pair were studied at approximately the same time. In this way similar soil moisture, temperature, and other climatic factors prevailed in the comparison of the members of each pair of crops. Since the work extended through the summer and fall, similar climatic conditions averaged about the same for the tests on the soils and the comparison of them is valid, although climatic conditions were not as strictly similar as in the comparison of the crops.

In 1943 similar comparisons were made on the Viola, Muscatine, and Clinton silt loams. These soils are of lesser extent in the area although important locally. The Muscatine is notably a deep, permeable soil while the Clinton is of moderate permeability and extensively represented in nearby areas.

On each site the standard method of using the Type-F infiltrometer was employed (*1*).[1] This provides an application of artificial rainfall to plots 6 feet by 12 feet in size with a

[1] Italic numbers in parentheses refer to Literature Cited, p. 29.

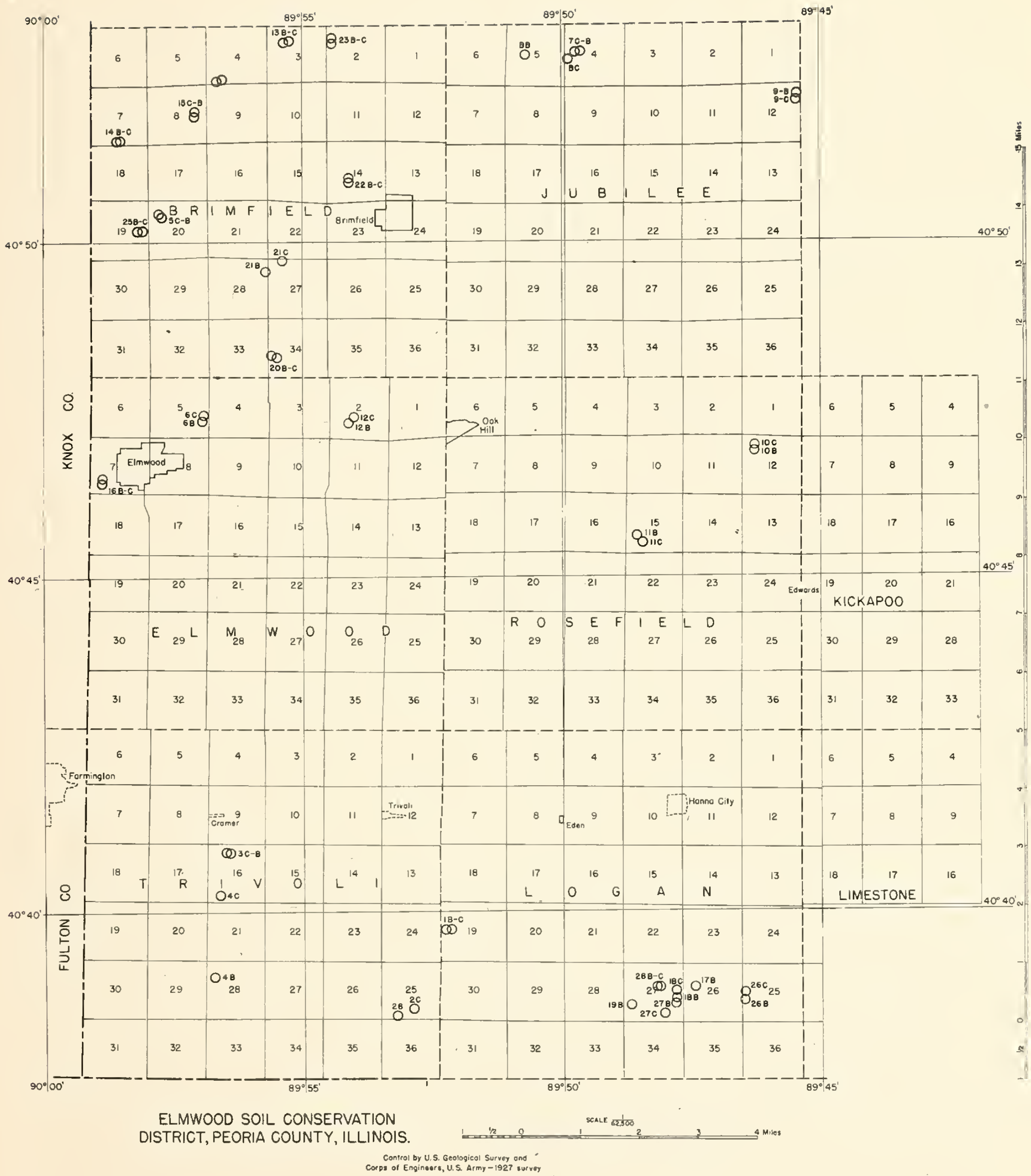


Figure 1.--Locations of infiltrometer plots in six townships ranging across center of supposed aquifer.

wetted border of approximately $1\frac{1}{2}$ feet in width. Hydrographs applicable to storms of 300-minute duration and intensity of 1.8 inches per hour were derived.

Watershed Studies

The necessity of establishing watersheds for a study of the interrelationships between rainfall, runoff, infiltration, soil moisture movement, and potential accretions to ground water was clearly apparent from the very beginning of the planning stage of the project. However, only after the infiltrometer survey had been completed did it become apparent that the watersheds selected for this phase of the study should provide a comparison of bluegrass and corn growing on the Tama and Berwick silt loams. To study these 4 conditions in triplicate required 12 watersheds. These were selected in consultation with soils specialists who checked carefully as to the possibility of inadvertent inclusion of soils other than those designated. This careful scrutiny as to uniformity of soil for any given watershed resulted in a very definite delimitation of size. The watersheds each approximated 3 acres in extent. They were located within the 6 townships previously sampled in the infiltrometer survey as shown in figure 1. The general plan was to locate 4 of the watersheds at each of the corners of a triangle. Thus any group of 4 watersheds had representative soils and vegetal-cover conditions and essentially similar rainfall and climatic conditions. The other groups of 4 were geographic replicates. In setting up the detailed plans of study, several premises were utilized, as follows:

(1) Evapo-transpiration comes entirely from the root zone.

(2) Depletion of soil moisture below field capacity is due primarily to withdrawal of moisture by plant roots.

(3) Percolation or the movement of gravitational water is that water in excess of field capacity that moves primarily through large noncapillary pores.

(4) Accretions of soil moisture to the soil profile below the root zone, in the main, do not return to the surface and are depleted either by movement to ground water or lateral movement to provide base flow of streams.

(5) Vapor movement is so slight that it is not necessary to attempt measurements of it.

Obviously, the conclusions that are drawn from this study are valid only within the limits of validity of these premises. It is believed, however, that any deviation from them, as may be shown by subsequent research, can involve no more than small magnitudes.

In general, the techniques employed in these watershed studies were standard, well-recognized methods:

(1) Rainfall was measured by means of 6-inch capacity nonreversing Friez recording raingages. One such gage and a Standard United States Weather Bureau Gage was located on each individual watershed. Precipitation in the form of snow was measured directly as to depth and sampled for water content. The total depth was then converted to inches of water.

(2) Runoff was measured by means of the Type-H flumes (fig. 2, p. 6) that had a 3.5-foot rated capacity. They were installed in concrete structures located in the drainageway of each watershed. Friez Type-FW-1 waterstage recorders were mounted upon the flumes to provide a continuous record of the depth of flow. The clocks of both the rainfall and runoff recorders were regularly compared with a master watch. In the initial phases of the work, 6-hour charts were used on all recorders, but these were later changed to 12-hour charts. After each storm the charts were changed and properly annotated to show corrected time and other pertinent information.

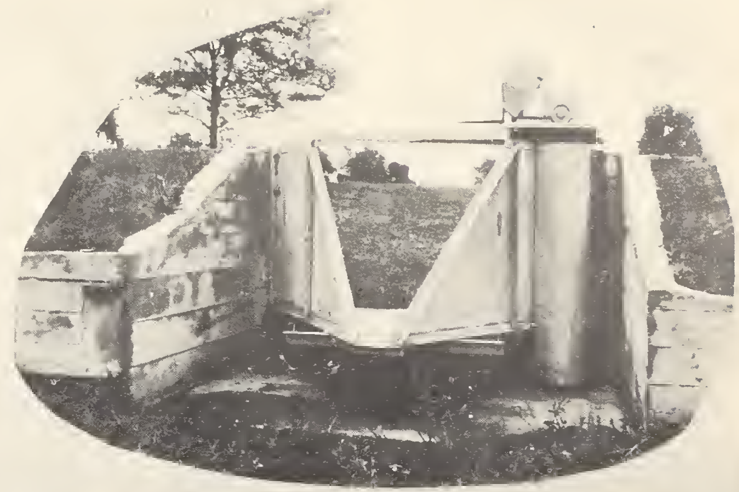
(3) Soil moisture was measured indirectly through the use of plaster of Paris gravimetric sorption blocks (fig. 2). The unit consists essentially of a plaster of Paris thimble fastened to the end of a transparent plastic conduit. A small plug or block which had been ground to fit the inside of the thimble was inserted through the tubing into the thimble in a manner such that it could be removed and weighed at any desired time. Further details as to the nature and operation of these sorption blocks have been given elsewhere (5).

These sorption blocks were calibrated in the laboratory for each horizon of each soil type. In practice it was found necessary to check the dry weight of the plugs at frequent intervals. Some difficulties resulted owing to the fact that after the porous plugs were once dried they did not quickly return to the moisture content of the soil which they were designed to measure. The soil moisture sorption blocks were installed at seven depths on each watershed: namely, 6 inches, 12 inches, 24 inches, 36 inches, 48 inches, 60 inches, and 72 inches.

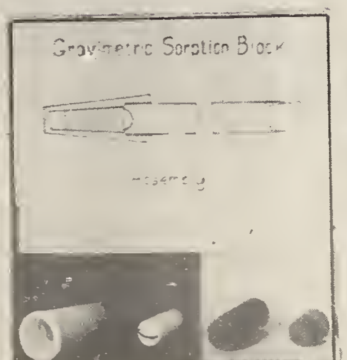
(4) Soil water movement was also measured directly in a manner not contemplated at the time the experiment was installed. After the experiment had been established it was found that during these abnormally wet years, free water entered the transparent tubing at its lower extremity and its rising and falling levels could be readily measured. It is believed that the sum of the recessions of the free water surface in these tubes represents at least as accurate a method of arriving at gravitational water movement as that derived from the data of the sorption blocks themselves. In any event, in the subsequent studies both sets of data were used and it will be seen that similar conclusions as to water movement may be drawn from either set of data.

(5) The methods differed from those of most previously reported studies in several respects. The four soil-cover complexes were studied on triplicated watersheds, the

WB-1, Type H flume and Raingages



Closeup of WB-1 Runoff Station



Thimble, Plug or Block
Synthane Tube & Stopper

Gravimetric Sorption Blocks Installed
Note one block removed for weighing

Torsion Balance and Case
Note Tripod & Line Levels

FIGURE 2.--Equipment and instruments used for the measurement of runoff and soil moisture.

members of each set of three having a single soil type, a single vegetal cover, and being as similar in size and slope as practicable. The extensive employment of sorption blocks as a means of maintaining a fairly continuous record of soil moisture at various depths throughout a 78-inch soil profile during the period of study while not necessarily ideal, did permit a computation of the consumptive use of water by crops under natural conditions. The entire plan comprises an attempt to determine the magnitude of, and relate to each other, a number of phases of the hydrologic cycle: rainfall, runoff, infiltration, soil moisture, the movement of water within the soil horizons, and the consumptive use of water by the crops on the watersheds.

RESULTS

Infiltration Survey

The results for each of the 40 plots studied are given in tables 9 and 10 of the Appendix, pages 31 and 32. A summary showing the average rate of infiltration is given in table 1, page 8, and the average amount in table 2, page 8.

The results showed consistently higher infiltration both in rate and amounts on the bluegrass than on the corn. The magnitude of the differences in both rate and amount of infiltration is greater on the more permeable Tama and Muscatine soils. However, even on the Berwick silt loam, the infiltration on the grass is nearly three times that on the corn, whether viewed from the standpoint of rate or total amount.

These results indicate that the type of land use in the area under study has marked effects on the rate and amount of infiltration. If these infiltration curves were applied to each of the natural storms occurring in a typical year, the increase in amount of water entering the soil under grass probably would exceed by more than 5 inches that entering the ground under corn. If all of this water should move downward to ground-water levels, it would more than meet the deficiency of approximately 5 surface inches that is now believed to occur. On the other hand, if a considerable amount of this gain in infiltration is intercepted and used by the grass, the net supply remaining for accretion to ground-water levels would be greatly reduced. Therefore the summarized data outlined above are of interest in indicating that land use does affect the rate and amount of infiltration occurring in the area. However, these infiltrometer studies do not provide any information as to the effect of demands of plants for water or the amounts of water moving below the root zone under natural field conditions. For these reasons the second phase of the study was promptly started.

Watershed Studies

The outstanding feature of climate in the calendar years of 1945 and 1946, during which these studies on the watersheds were conducted, is the large amount of rainfall that occurred, particularly during the spring period. In figure 3, page 9, the monthly rainfall for each of these years is compared to the normal rainfall. In figure 4, page 10, the cumulative total rainfall for each year is compared with the normal rainfall as reported by the four nearest Weather Bureau stations. It will be noted that in 1945 the months of March, April, May, and June, in particular, were much wetter than normal. In 1946, the months of March,

TABLE 1.--*Rate of infiltration at end of 5-hour storm*

Soil	Bluegrass pasture	Corn land	Difference due to land use
	Ins./hr.	*Ins./hr.*	*Ins./hr.*
Berwick silt loam	0.34	0.12	0.22
Tama " "	.77	.14	.63
Viola " "	.16	.08	.08
Muscatine " "	.61	.11	.50
Clinton " "	.29	.18	.11

TABLE 2.--*Total amount of infiltration during 5-hour storm*

Soil	Bluegrass pasture	Corn land	Difference due to land use
	Inches.	*Inches.*	*Inches.*
Berwick silt loam	3.48	1.21	2.27
Tama " "	5.03	1.51	3.52
Viola " "	1.63	1.28	.35
Muscatine " "	5.38	1.34	4.04
Clinton " "	2.77	2.17	.60

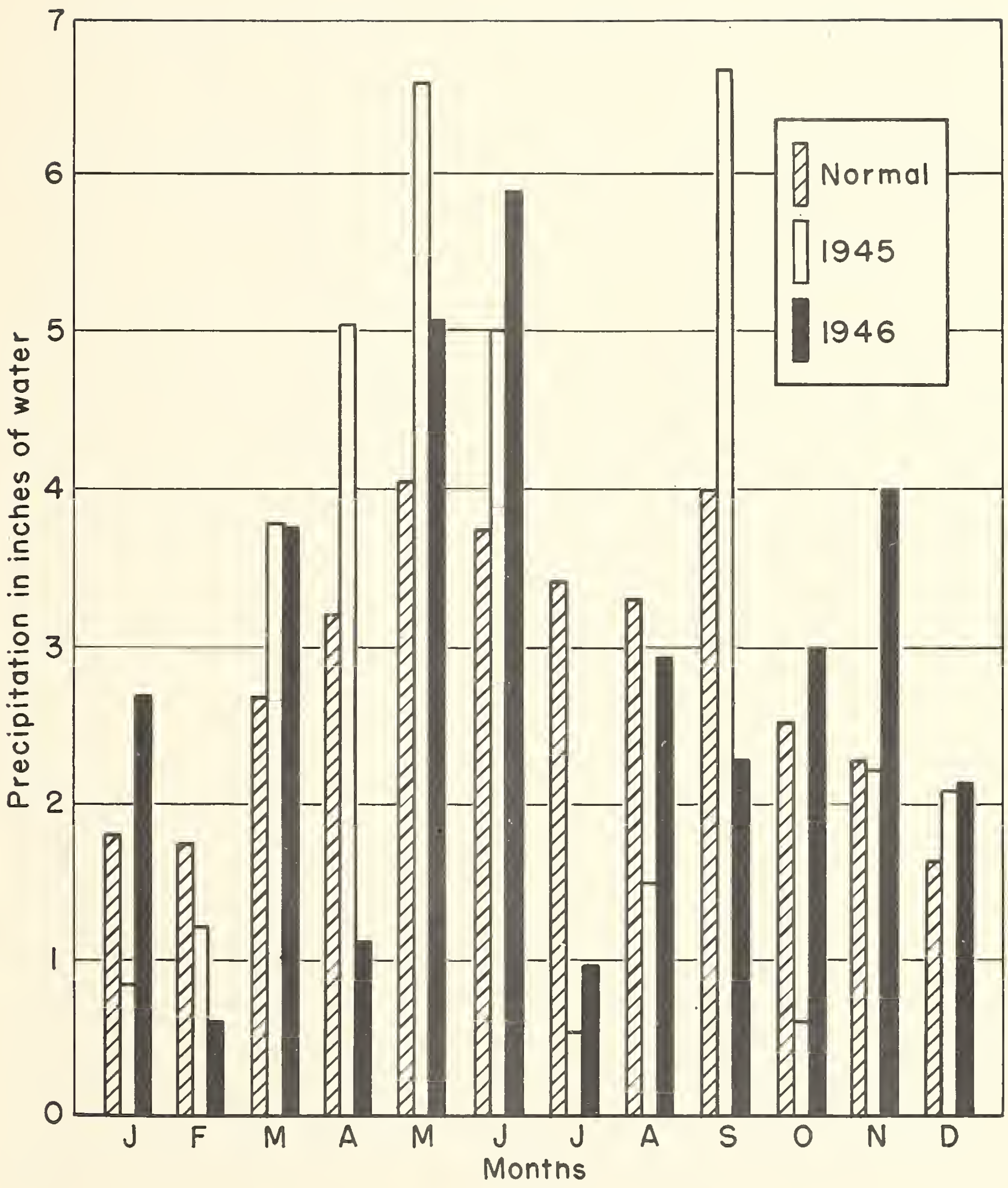


FIGURE 3.--Monthly rainfall, 1945 and 1946, in comparison with normal, based on four U. S. Weather Bureau stations located in the area.

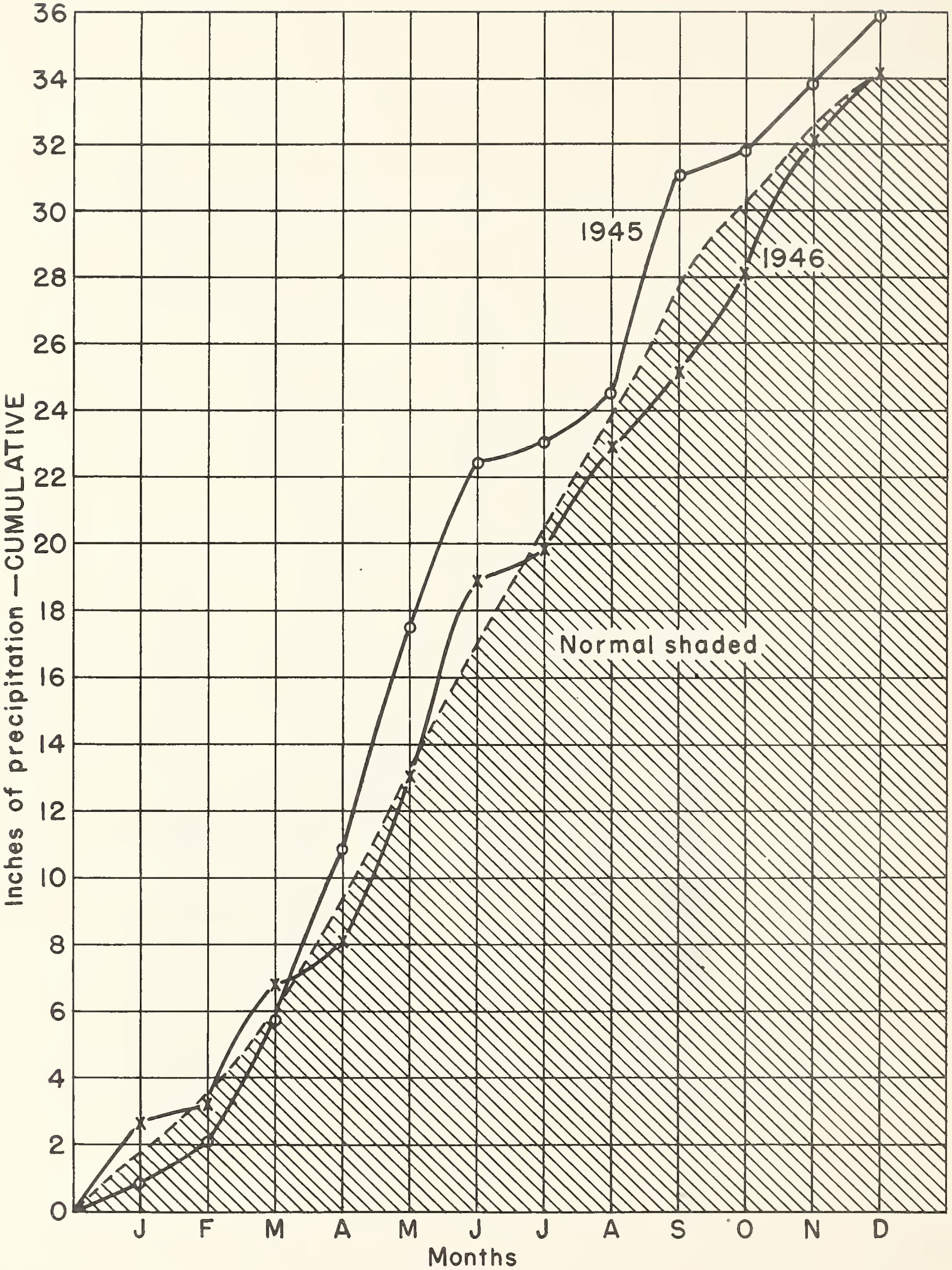


FIGURE 4.--Cumulative rainfall, 1945 and 1946, in comparison with normal, based on four U. S. Weather Bureau stations located in the area.

May, and June exceeded normal by considerable amounts. In view of existing data on moisture use and movement, it is worth noting also that during July and August, which are the months when corn particularly draws upon soil moisture, the rainfall in 1946 exceeded that of 1945.

The excesses in the spring were sufficient in both years to have an appreciable effect upon farm operations. Corn was planted about a month later than usual. In all likelihood this excess moisture also affected the depth of root penetration. This appears to be borne out by the data presented subsequently.

Although the 12 watersheds were located in 4 different townships **(fig. 5, p. 12)**, it will be seen from the detailed data on rainfall that there was no consistent or large difference from one watershed to another. Inasmuch as the corn and bluegrass watersheds were located in pairs closely adjacent to each other, the difference in rainfall between pairs was even less than that of the entire group of 12 watersheds. In 1945 the maximum difference between pairs of watersheds was 0.64 inch and in 1946 it was 0.54 inch per annum.

No other notable features of climate appeared to differ greatly from normal and no special comparisons of them have been made.

The Berwick and Tama soils have been described in various technical reports (3), (7). As previously noted, the Tama is a typical prairie soil of considerable depth and above average permeability. The Berwick soil is a soil that developed under timber and is much less permeable. A comparison of the volume weights of the two soils at each of the seven depths at which sorption blocks were placed is given in table 3, page 13.

It will be seen from **table 3** that the volume weight ratio for the Berwick soils is greater than that of the Tama in each of the first four depths of measurement. At the 42- to 54-inch depths and from there to the 78-inch depth, the Tama averages a little heavier than the Berwick.

The volume weight figures are in general agreement with those reported for certain Illinois silt loams by Harland and Smith (3).

WATERSHED CHARACTERISTICS

The watersheds, though generally similar, differ unavoidably in certain respects. Their size is determined in part by the prevailing drainage pattern and is limited by a rigorous adherence to the specified soil type. The slopes of the Tama watersheds, it will be noted from tables 4 and 5, pages 14 and 15, are greater than those of the flatter Berwick soil. (See **figs. 12 and 13**, pp. 33 and 34.) In orientation five of them face in a generally easterly direction, three southerly, two westerly, and two northerly (fig. 6, p. 16).

Depth of root penetration on the various watersheds of the study is an important item in view of the premises that have been set up, namely: that depletion of soil moisture below field capacity is due only to the withdrawal of moisture by plant roots; and, further, that the accretions of soil moisture to the soil profile below root zone can be taken as an index of the amount of water potentially available to ground water or to provide base flow of streams. An excellent opportunity to determine the depth of root penetration on the 12 watersheds resulted from the various kinds of studies that were being made. One of these was the sampling of the profiles to obtain volume weight determinations, another was the operations that were necessary in installing the sorption blocks at the 7 different depths in the profiles. On the basis of such continuing observations during the period of study, it was

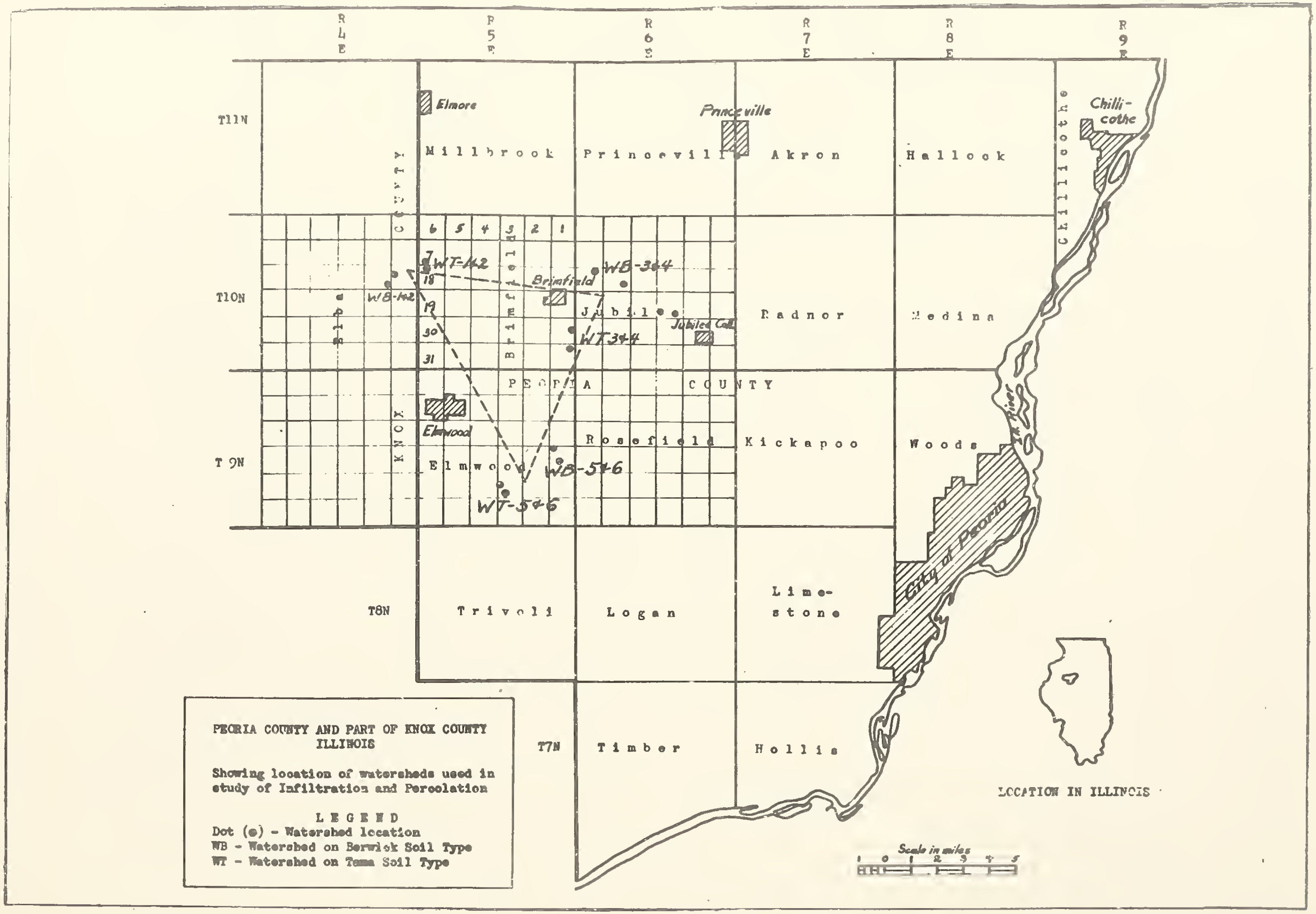


FIGURE 5.--Location of watersheds.

TABLE 3.--*Comparison of volume weights of the two soils*

BERWICK

Inches depth	0–9	9–18	18–30	30–42	42–54	54–66	66–78
Watersheds							
B-3.............	1.32	1.35	1.37	1.34	1.37	1.36	1.34
B-4.............	1.25	1.32	1.26	1.36	1.31	1.43	[1] 1.46
B-5.............	1.34	1.29	1.28	1.34	[1] 1.32	[1] 1.43	[1] 1.46
B-6.............	1.20	1.48	1.28	1.33	1.32	1.43	1.46
Average..........	1.28	1.36	1.39	1.34	1.33	1.41	1.43

TAMA

T-3.............	1.21	1.17	1.19	1.33	1.45	1.54	1.54
T-4.............	1.24	1.17	1.27	1.27	1.32	1.32	1.46
T-5.............	1.25	1.16	1.25	1.44	1.46	[1] 1.54	[1] 1.54
T-6.............	[1] 1.24	[1] 1.17	[1] 1.27	[1] 1.27	[1] 1.32	[1] 1.32	[1] 1.46
Average..........	1.24	1.17	1.24	1.33	1.39	1.43	1.50

[1]Estimated basis of data from a similar watershed.

TABLE 4.--*Watershed characteristics and land use record--cultivated watersheds*

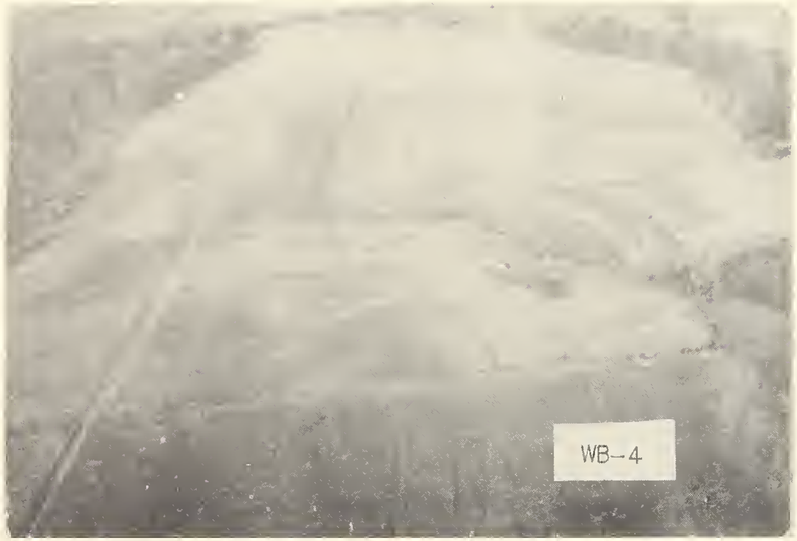
	B-2	B-4	B-6	T-2	T-4	T-6
Soil	Berwick	Berwick	Berwick	Tama	Tama	Tama
Size in acres	2.282	2.786	2.408	1.882	2.057	5.348
Average slope	1-3%	1-3%	1-3%	4-7%	4-7%	4-7%
Surface drainage	poor	fair	fair	good	good	good
Exposure	north	east	north	east	south	west
Vegetative cover 1945		First year--corn after hay				
plowed	4/11	5/28	5/28	4/11	5/28	4/7
planted	6/3	5/29	5/29	6/2	6/6	5/23
cultivated 1st time	6/13	6/14	6/14	6/12	6/18	6/3
2d "	6/22			6/19	7/3	6/12
3d "	7/5			7/8		6/21
Average height (inches)						
6/9/45	1	1	1	1	1	2
7/6/45	18	18	12	15	10	24
9/14/45	70	60	50	72	60	80
Frost killed		All the corn was frost killed by Oct. 9				
Yield--Bu/a	38	30	30	58	21	60
Root penetration (inches)[1]						
11/13/45	5-8	8-10	8-10	8-10	8-10	13-15
Vegetative cover 1946		Second year corn				
plowed		All seed beds were ready by 5/17/46				
planted	5/11	5/28	6/4	5/22	5/29	5/22
cultivated 1st time	6/1	6/15	6/18	6/1	6/10	6/1
2d "	6/5	6/24	6/28	6/10	6/24	6/7
3d "	6/26			7/1		6/29
Average height (inches)[1]						
5/29/46	2			2		
6/10/46	4	2	1	6	2	6
7/5/46	24	18	16	24	16	24
7/26/46	72	66	60	80	60	80
Frost killed		All corn was frost killed by October 28				
Yield--Bu/a	40	35	40	60	58	50
Root penetration (inches)[1]						
8/12/46	12-14	12-14	12-14	16-17	16-17	16-17

[1]Root penetration figures represent the depth of 75% of roots and greatest depth of visible hair roots.

TABLE 5.--*Watershed characteristics and land use record--pasture watersheds*

	B-1	B-3	B-5	T-1	T-3	T-5
Soil	Berwick	Berwick	Berwick	Tama	Tama	Tama
Vegetative cover	All watersheds were in Bluegrass					
Size in acres	1.276	2.607	1.934	2.023	2.404	2.763
Average slope	1-3%	1-3%	1-3%	4-7%	4-7%	5-7%
Surface drainage	poor	fair	good	good	good	good
Exposure	south	south	east	east	east	west
Grazing	light	light	moderate	moderate	moderate	moderate
Stand of grass	good	good	good	good	good	good
Dormancy	All pastures were dormant during the period December through February					
Root penetration (inches)[1]						
11/13/45	15-17	15-18	16-17	15-27	15-27	15-27
8/12/46	15-24	10-20	15-20	17-32	16-32	17-36

[1]Root penetration figures show that the profile above this range of depth contains 75% of the roots.



CORN BLUEGRASS

Typical watersheds on Berwick Soil Type

CORN BLUEGRASS

Typical watersheds on Tama Soil Type

FIGURE 6.--Aerial photographs of typical Berwick and Tama watersheds.

concluded that for these conditions and under the prevailing rainfall, which as previously shown was abnormally high particularly during the spring months, no great number of roots of either type of vegetation penetrated beyond the depth of 18 inches.

Rainfall, Runoff, and Indicated Infiltration

While the data from individual storms that occurred during the period of study have been analyzed, space does not permit including these details in the present report. The annual totals, however, for each of the watersheds are of interest and are shown in table 6, page 18. In this table, in addition to rainfall, runoff, and rainfall-minus-runoff, which is taken as an index of infiltration, there is also included a column giving the computed consumptive use of water on each of the watersheds during the 2-year period. Consumptive use is water leaving the root zone but which does not arrive in the subroot zone. Admittedly, the calculation is possibly more truly relative than absolute. The method of calculation itself, it should be noted, includes in "consumptive use" the amount of water that was intercepted by prevailing vegetation. It is in error by the amount of lag in the response of the sorption blocks to the change in moisture in the soil. It is believed that this error might have been appreciable for certain short intervals of time. On the other hand, when periods of several months are used, the proportion of water involved in the tardy response of the sorption blocks is small, and such errors are largely reduced or practically eliminated.

In table 6, the columns headed "rainfall" and "runoff" are self-explanatory. The difference between them is taken as an indication of infiltration, but in actuality it includes the amount of water required to wet the surface of the ground and the vegetation. "Water leaving root zone" includes both the water used by plants and that moving downward to lower levels. When the amount arriving at the 18-78-inch depth is subtracted from it and correction made for gain or loss in storage, there is derived the amount of water used by the crop as shown in the column "consumptive use." The amount of water leaving the subroot zone of course approximates in any considerable period of time, the amount arriving. However, in any short period of time it may be either more or less than the amount added in the same period.

The data for the 1946, the second year of the work during which some refinements in technique were accomplished, are believed to be somewhat more substantial and reliable than those of the first year, 1945. Observable in the table are the greater amounts of water used by the bluegrass than by the corn, despite the greater amount of runoff occurring from the latter.

The recession of free water represents the summation of the successive draw-downs of water in the miniature test wells represented by the synthane tubes. It is observably greater for the areas in corn than those in bluegrass. This is to be expected from the fact that more water is available,since less of it was utilized by the corn than the grass.

The indicated infiltration (taken as rainfall minus runoff) differs in toto only slightly for the two crops. In 1945 it averaged 30.90 inches for the bluegrass and 29.33 inches for the corn. In 1946 it averaged 26.23 inches for the bluegrass and 24.62 inches for the corn. Thus there is a difference of about $1\frac{1}{2}$ inches each year.

The amount of water leaving the root zone, which includes evapo-transpiration as well as water moving to greater depths, averaged 30.93 inches for the bluegrass and 28.53 inches for the corn in 1945. That from the bluegrass again exceeded that from the corn in the following year when 28.31 inches and 25.28 inches of water left the root zone in one form or

TABLE 6.--*Summary of annual rainfall, runoff, and soil water movement 1945 and 1946, Elmwood, Ill.*

MARCH 20 TO DECEMBER 31, 1945

Soil type	Cover and watershed No.	Rainfall	Runoff	Rainfall minus runoff	Water movement from sorption blocks: Leaving root zone	Water movement from sorption blocks: Arriving 18"–78"	Water movement from sorption blocks: Leaving 18"–78"	Recession of free water	Consumptive use
		Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
Berwick	Bluegrass								
	B-1	33.38	0.84	32.54	32.53	15.39	14.84	12.97	17.14
	B-3	32.14	.86	31.28	30.95	10.25	11.03	5.46	20.70
	8-5	31.37	.97	30.40	32.03	16.60	17.02	15.15	15.43
Tama	Bluegrass								
	T-1	33.75	2.33	31.42	31.19	8.76	9.93	5.98	22.43
	T-3	31.60	2.29	29.31	28.59	7.56	6.34	4.86	21.03
	T-5	30.81	.34	30.47	30.32	8.64	7.58	4.02	21.68
Berwick	Corn								
	8-2	33.53	3.09	30.44	30.26	12.38	9.56	10.13	17.88
	B-4	32.28	3.22	29.06	26.59	9.46	8.60	6.39	17.13
	B-6	30.81	4.41	26.40	25.86	10.91	9.79	9.75	14.95
Tama	Corn								
	T-2	34.25	2.92	31.33	31.13	12.45	13.23	11.26	18.68
	T-4	32.24	1.75	30.49	29.79	8.16	7.22	6.04	21.63
	T-6	30.99	2.72	28.27	27.57	15.07	13.74	10.86	12.50

JANUARY 1 TO OCTOBER 24, 1946

Soil type	Cover and watershed No.	Rainfall	Runoff	Rainfall minus runoff	Water movement from sorption blocks: Leaving root zone	Water movement from sorption blocks: Arriving 18"–78"	Water movement from sorption blocks: Leaving 18"–78"	Recession of free water	Consumptive use
Berwick	Bluegrass								
	B-1	25.30	.24	25.06	27.27	8.56	11.69	5.86	18.71
	8-3	26.73	.14	26.59	28.29	7.48	8.30	4.84	20.81
	8-5	27.20	.09	27.11	29.87	9.38	9.54	4.80	20.49
Tama	Bluegrass								
	T-1	24.52	.45	24.07	27.43	5.62	7.03	2.58	21.81
	T-3	26.92	.16	26.76	27.72	5.02	6.58	2.62	22.70
	T-5	28.00	.18	27.82	29.26	6.65	9.89	2.40	22.61
8erwick	Corn								
	B-2	25.06	1.71	23.35	25.07	8.89	9.91	8.66	16.18
	B-4	26.81	1.48	25.33	25.53	11.94	12.11	9.96	13.59
	8-6	27.05	2.43	24.62	25.61	12.89	12.75	9.11	12.72
Tama	Corn								
	T-2	25.06	1.42	23.64	23.58	8.49	8.69	6.78	15.09
	T-4	26.13	1.31	24.82	25.08	12.98	15.34	8.95	12.10
	T-6	27.75	1.79	25.96	26.81	15.15	16.05	12.78	11.66

the other. Recalling that the watersheds were paired as to location (B_1 and B_2 being adjacent to each other, B_3 and B_4, etc., likewise) it is important to note that in 11 of the 12 pairs of comparisons the removals from the bluegrass areas exceeded those from the corn areas.

The amount of water arriving in the subroot zone as indicated by the sorption blocks averaged 11.20 inches under bluegrass and 11.41 inches under corn in 1945. The following year the amounts were 7.12 inches under bluegrass and 11.72 inches under corn.

The seasonal trends in soil moisture movement are shown graphically in figures 7 and 8, pages 20 and 21. The curve labeled "water entering the root zone" is essentially rainfall minus runoff. No adjustments for canopy interception or for evaporation were incorporated in the calculations. "Water leaving the root zone" was calculated as rainfall minus runoff, plus indicated soil moisture losses minus indicated soil moisture gains in the upper 18 inches of soil. "Water passing below the root zone" is a summation of the indicated gains in soil moisture in the depth between 18 and 78 inches of soil.

The period August 18 to October 9, 1945, was eliminated from these calculations, since all of the sorption blocks had been removed at the beginning of this period to recheck and renew the tare weights.

"Water passing below 78-inch depth" reflects the summation of the water losses in the subroot zone, namely 18 to 78 inches.

The residue of water leaving the root zone which did not pass downward is regarded as "consumptive use." This term has been defined by the Committee on Abscrption and Transpiration, Section of Hydrology, American Geophysical Union, as that "water used by plants, the water evaporating from the soil, and the rainfall intercepted by the vegetal canopy."

It will be noted from the curves showing water passing below root zone that the highest rate of movement occurs during the spring period and that period before vegetation reaches maximum development. The total amount of this water is unexpectedly high. The average of all four complexes is 11.3 inches for 1945 and 9.42 inches for 1946. This is an amount which, if applied over only half of the presumed area of the aquifer, probably would yield an amount of water in excess of the estimated depletions of ground water. However, it must be recognized that a part of this water is required to provide base flow to the streams of the area.

Another perhaps more conservative calculation of this water potentially available for accretion to ground-water levels or to provide base flow of streams is possible. Using the sum of the recessions of free-water levels of the miniature test wells, the 1945 average for all four soil-cover complexes is 8.57 inches and the 1946 average is 6.61 inches. These smaller figures exclude all water not under sufficient hydrostatic head to enter and rise within the synthane tubes. Interestingly enough, it correlates significantly with the values secured from the sorption blocks, although consistently smaller in magnitude. (See also figs. 14 and 15.)

The actual distribution of the water and its final disposal below the 78-inch depth of soil, while a matter of extreme interest, involves a problem beyond the scope of this study. It indicates here the need for additional research that will definitely and positively show what, if any, relations exist between phenomena at the ground surface and the depths of the ground-water table. The problem involves questions of geology as well as ground water, and includes likewise matters related to regimen of rivers and their tributaries that pass

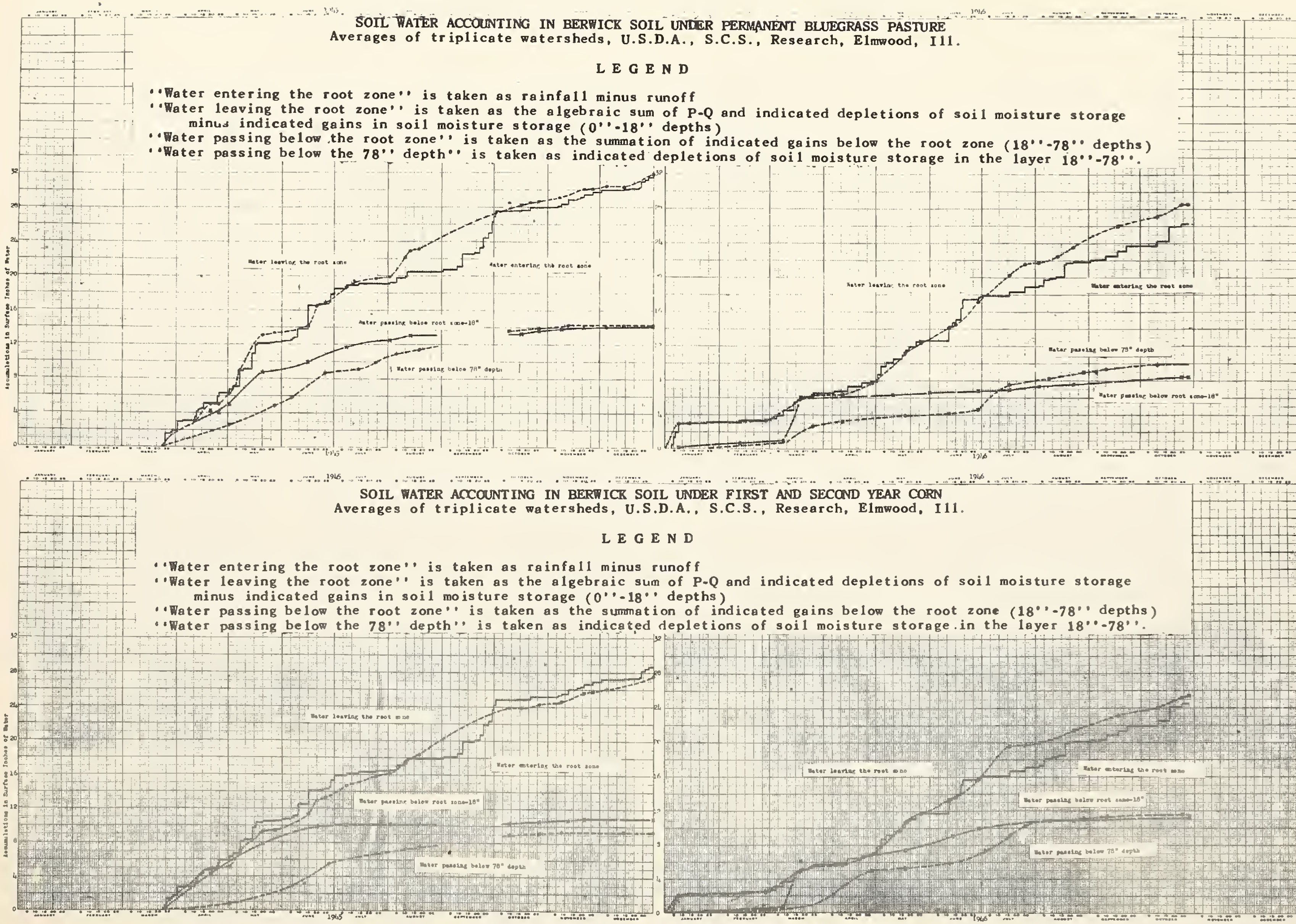
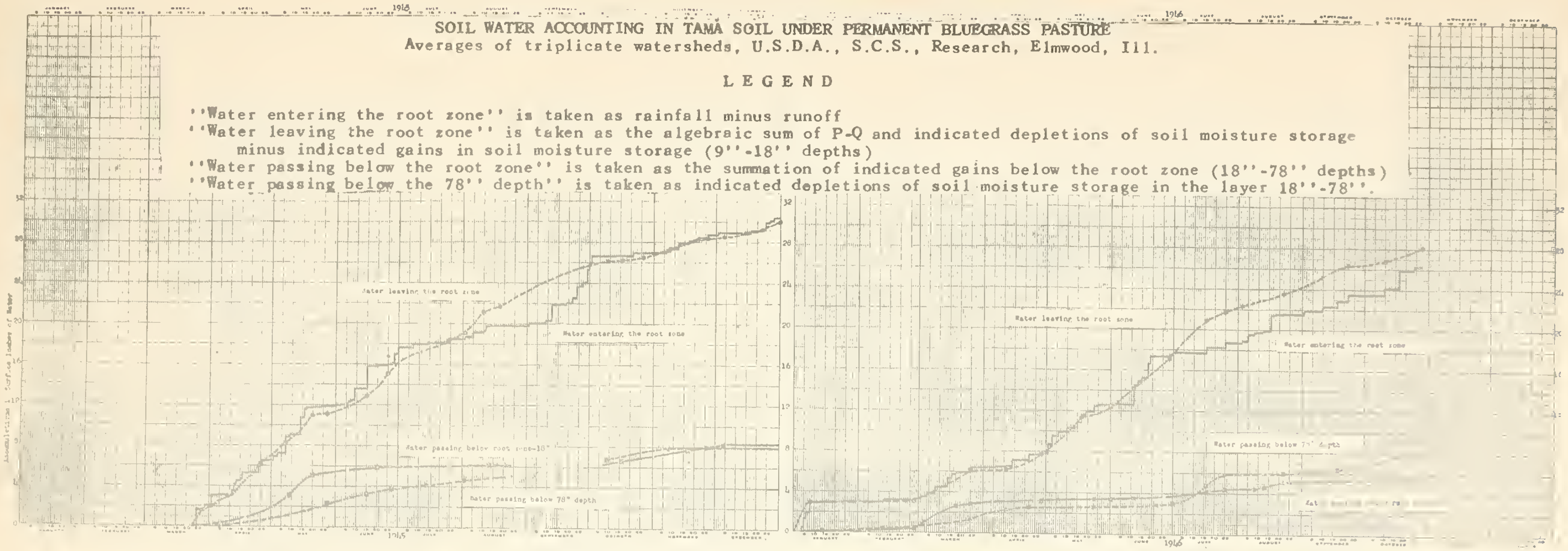


FIGURE 7.--Accounting of soil water in the Berwick soil under bluegrass and under corn.



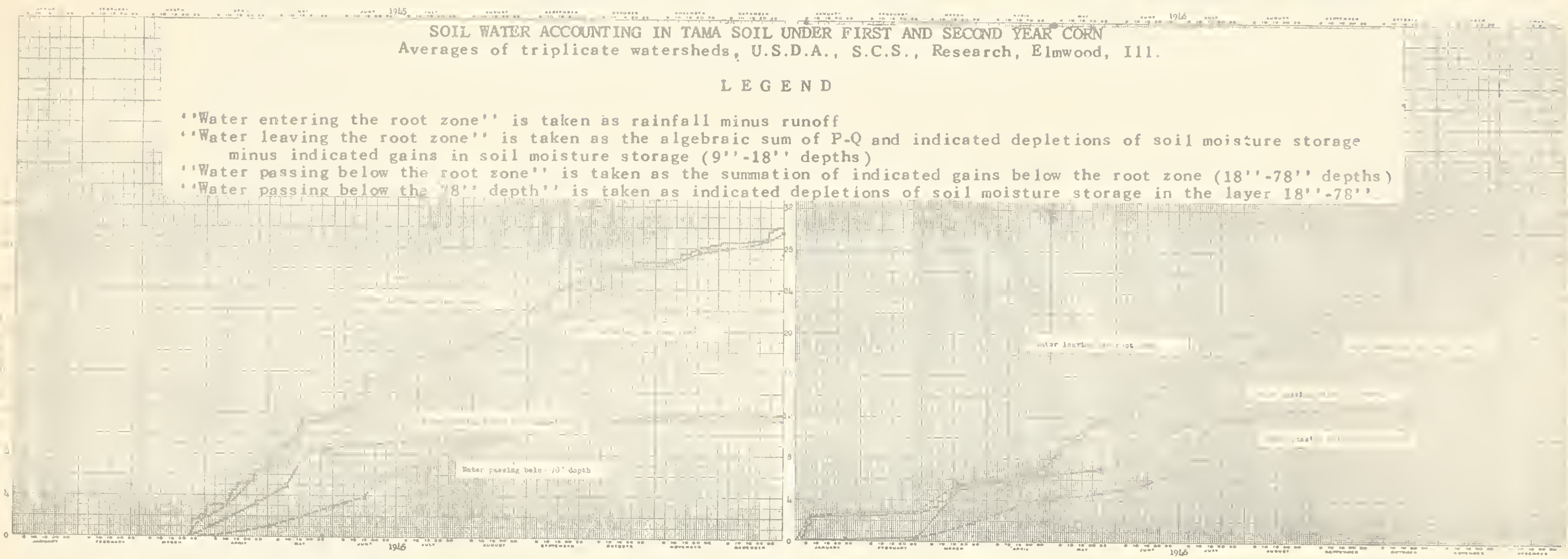


FIGURE 8.--Accounting of soil water in the Tama soil under blue grass and under corn.

through the area.

The differences in consumptive use of water by grass and by corn on the Tama and the Berwick silt loams during each of 2 years is shown in the last column of table 7, page 23. It is seen that the calculated amounts of consumptive use of water, even though previously pointed out as subject to certain errors, nevertheless shows a fairly consistent trend among the separate watersheds during the 2 years of study. On 10 of the 12 comparisons between paired watersheds which are available, the consumptive use of the grass exceeds that of the corn. In the two exceptions, both of which occurred in the first year of the study, the amount of excess use by the corn is comparatively small.

The differences in consumptive use by the grass and corn are greater on the more permeable Tama than on the Berwick in both years. There are, of course, several possible explanations for this. Infiltration on the Tama was greater than on the Berwick and somewhat more water was available for use by the plants on this more permeable soil. The fact that plant growth is better on the Tama than on the Berwick may or may not be the explanation, since the growth of corn was better as well as the growth of grass. For example, on August 20, 1945, the corn on the three Tama watersheds was recorded as having average heights of 8 feet, 7 feet, and 9 feet, while on the Berwick watersheds it was only 5 feet, 4 feet, and 7 feet. It might be supposed, therefore, that during the period when corn was demanding a considerable amount of water, no great differences in consumptive use between grass and corn existed. In the remainder of the year, however, the grass on the Tama, being more vigorous, was utilizing more water than the grass on the Berwick silt loam.

Another item in the comparison presented in table 7 is that the differences in consumptive use between grass and corn were greater during 1946 than in 1945. Rainfall and the amount of infiltration, however, were less in 1946 than they were in 1945.

The amount of water used by corn as shown in table 7 may be compared with similar data previously reported from Iowa (4). Data for corn derived in an entirely different manner and grown on another aeolian soil showed amounts of 19.02, 22.34, and 17.43 inches for the years 1934, 1935, and 1936. While the agreement in magnitude is no more than general, still it is interesting to note that no wide differences between these data from Iowa and those of the present study in Illinois were found, particularly since the 1934 and 1936 years were very hot and dry while 1945 and 1946 were of above average rainfall.

Further, unpublished data from the Iowa experiments show that for the period 1935 to 1941, inclusive, (at which time the experiment was discontinued) the use of water by corn was 82 percent of that utilized by the grass. The corresponding figures derived from table 7 are 79 percent for 1945 and 64 percent for 1946. The point of interest is that in both experiments the amount of water utilized by the grass exceeded that of corn and that the respective magnitudes are generally similar.

Effects of Different Grasses on Soil Moisture

In unpublished studies of soil moisture by Carleton (2), the content of soil moisture in an orchard having different grasses as cover crops was determined. A part of the area growing each kind of grass was sprayed on June 13 with a weed killer. The determinations of soil moisture which were made on June 26 and June 30 following, showed a consistent decrease in moisture on the areas where live grass was present below those where the grass had been sprayed with weed killer. In this short interval of 13 to 17 days the differences ranged from about 1.5 percent to approximately 5 percent as shown in table 8, page 24.

TABLE 7.--*Comparison of consumptive use of water by grass and corn on replicated watersheds*

1945

Soil type	Watershed No.	Grass	Watershed No.	Corn	Difference
		Inches.		*Inches.*	*Inches.*
Tama silt loam	T-1......	22.43	T-2......	18.68	3.75
	T-3......	21.03	T-4......	21.63	- .60
	T-5......	21.68	T-6......	12.50	9.18
Average		21.71		17.60	4.11
Berwick silt loam	B-1......	17.14	B-2......	17.88	- .74
	B-3......	20.70	B-4......	17.13	3.57
	B-5......	15.43	B-6......	14.95	.48
Average		17.76		16.65	1.10

1946

Soil type	Watershed No.	Grass	Watershed No.	Corn	Difference
Tama silt loam	T-1......	21.81	T-2......	15.09	6.72
	T-3......	22.70	T-4......	12.10	10.60
	T-5......	22.61	T-6......	11.66	10.95
Average		22.37		12.95	9.42
Berwick silt loam	B-1......	18.71	B-2......	16.18	2.53
	B-3......	20.81	B-4......	13.59	7.22
	B-5......	20.49	B-6......	12.72	7.77
Average		20.00		14.16	5.84

TABLE 8.--*Soil moisture under unsprayed grasses and grasses sprayed with weed killer at Geneva, N. Y.*

Cover crop	Soil depth	Soil moisture under		Difference
		Untreated	Treated	
	Inches.	*Percent.*	*Percent.*	*Percent.*
Field brome	0-6	11.0	14.8	3.8
	6-12	10.9	15.8	4.9
Perennial rye grass	0-6	12.0	14.1	2.1
	6-12	13.5	15.3	1.8
Brage orchard	0-6	12.7	14.1	1.4
	6-12	12.3	15.4	3.1
Creeping red fescue	0-6	12.9	15.0	2.1
	6-12	13.6	16.5	2.9
Tall fescue	0-6	13.4	17.4	4.0
	6-12	12.5	17.3	4.8

The Relationship Between Consumptive Use and Downward Movement of Water in the Soil

When rain falls upon a vegetated area and infiltration occurs, the needs of the plants for moisture are apt to be satisfied at least in part as the moisture moves through the root zone. The more of this water is utilized by the plants, the less there remains for possible transmission to depths below root zone.

In the present study opportunity was provided to examine this relationship quantitatively. Data were available from two independent sources (sorption blocks and free water recessions) on the amount of movement below root zone. The amount of consumptive use of water by the plants was calculated as shown previously. The relationship between the amount of water consumed and the amount passing below root zone is shown in figures 9 and 10, pages 26 and 27.

The regression line has about the same slope regardless of the parameter of moisture that is used, and indicates that for each inch of consumptive use, the amount of water moving downward below root zone is reduced about three-fourth inch.

The correlations are highly significant and not greatly different for either parameter, being -0.936 for free water recessions and -0.916 for water measured by the sorption blocks.

The seasonal use of water by the corn and the bluegrass is illustrated by figure 11, page 28, which shows the relative amounts used monthly during one of the years of the study.

It is apparent that during the months of June, July, August, and September no consistent difference in amounts used by the two crops occurred. Both of them utilized perhaps most of the water available. The big difference occurred in the fall, winter, and spring, when corn was absent or dormant and the grass was utilizing water. The evapo-transpiration shown for corn in March, April, and May is largely evaporation because the corn was not planted before the end of May and also because transpiration from weeds was negligibly small, with very few of them present.

It may be speculated that generally under field conditions plants do use during their period of maximum growth most of the available water in the soil and that differences in amount used by different kinds of plants are related more to their period of maximum growth than to any special plant characteristics.

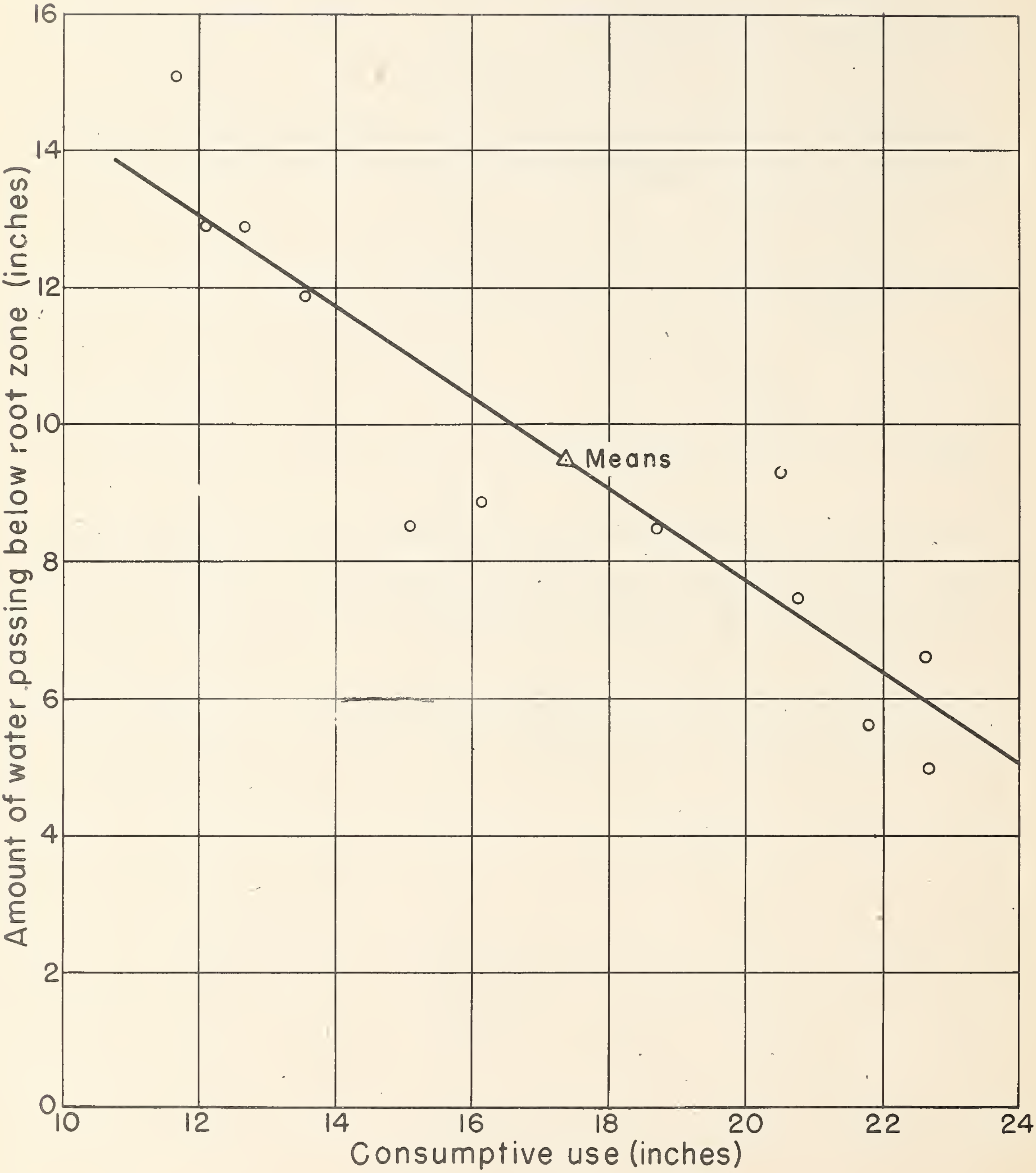


FIGURE 9.--Relation between amount of consumptive use and amount of free water moving below root zone, 1946.

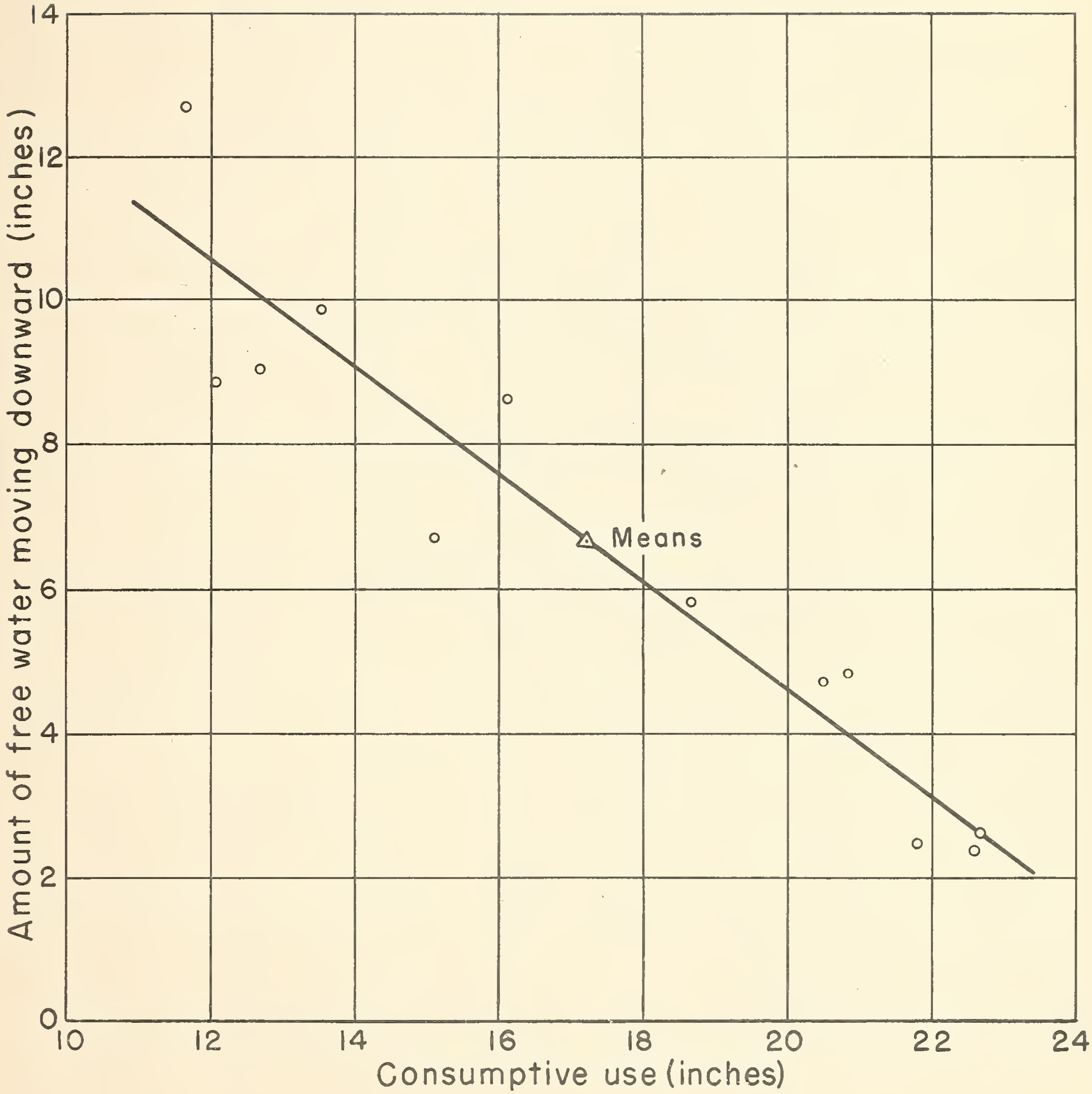


FIGURE 10.--Relation between amount of consumptive use and amount of water moving below root zone in 1946, as measured by sorption blocks.

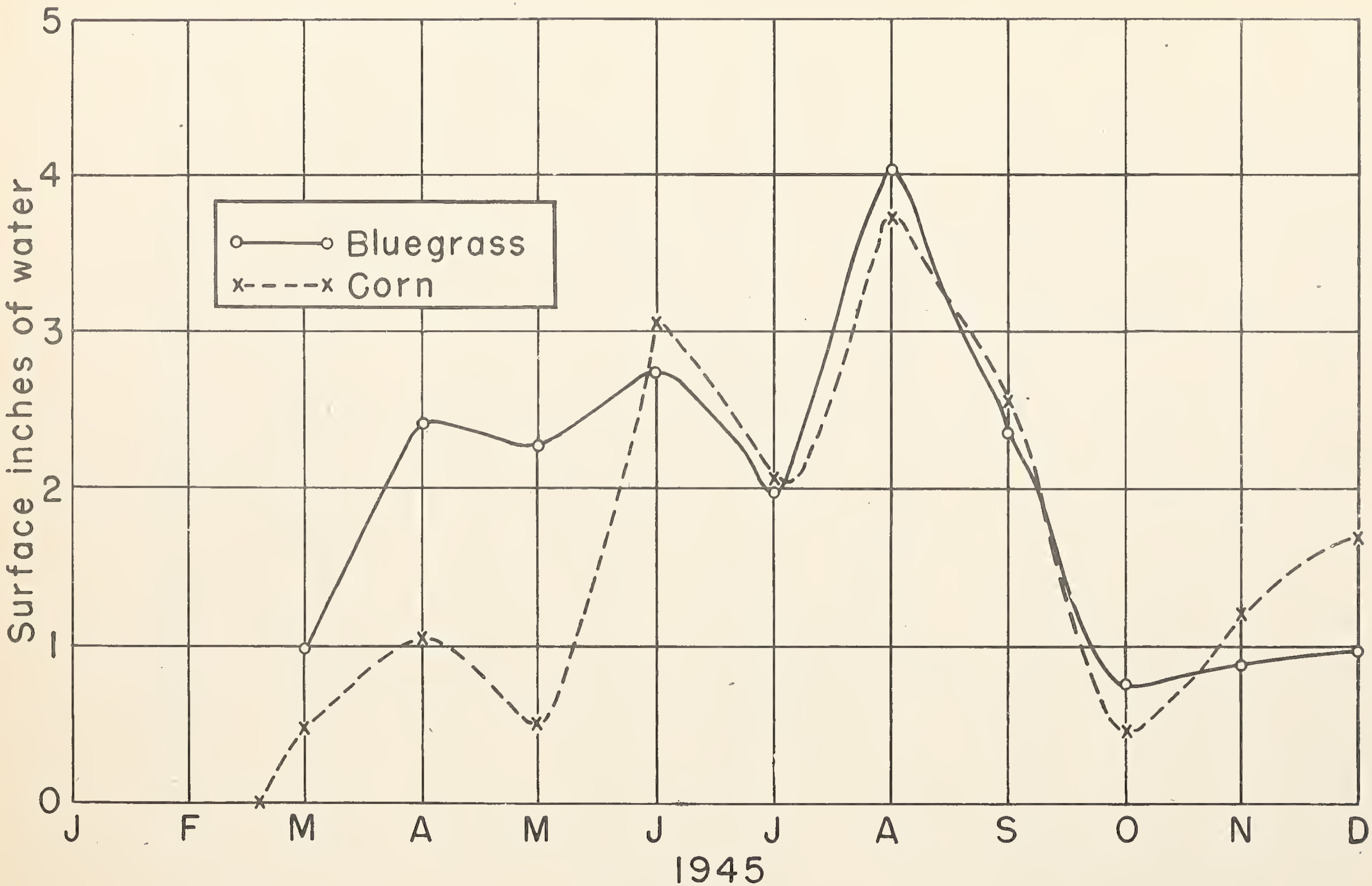


FIGURE 11.--Seasonal consumptive use of water by corn and bluegrass.

SOIL CONSERVATION SERVICE, WASHINGTON, D.C., 1948

LITERATURE CITED

(1) Anonymous
1941. STANDARD PROCEDURE FOR OPERATION OF TYPE F INFILTROMETER.

(2) Carleton, E. A.
1947. SOIL MOISTURE UNDER ORCHARD COVER--TREATED AND UNTREATED WITH HERBICIDE--AT GENEVA. Progress Report from the Arnot, Marcellus, and Geneva, N. Y., Soil Conserv. Expt. Sta. Unpublished.

(3) Harland, M. B., and Smith, R. S.
1928. VOLUME WEIGHT OF CERTAIN FIELD SOILS. Jour. Amer. Soc. Agron. 20: 533-541.

(4) Musgrave, G. W., and Neal, O. R.
1937. RAINFALL AND RELATIVE LOSSES IN VARIOUS FORMS. Trans. Amer. Geophys. Union II: 349-355, illus.

(5) Slater, C. S., and Bryant, J. C.
1946. COMPARISON OF FOUR METHODS OF SOIL MOISTURE MEASUREMENT. Soil Sci. 61: 131-155, illus.

(6) Suter, M.
1943. A PILOT STUDY OF GROUND-WATER RESOURCES IN PEORIA CO., ILL. Trans. Amer. Geophys. Union. II: 493-500.

(7) Wascher, H., Smith, R. S., and Smith, L. H.
1937. PUTNAM COUNTY SOILS. Ill. Agr. Expt. Sta. Soil Rept. No. 60, illus., 30 pp.

APPENDIX

TABLE 9.--*Rate of infiltration at various times from start of test--infiltrometer survey, Peoria County, Ill.*

Plot	Date	Soil	Bluegrass: Time in minutes from start of test 30	60	90	120	150	180	240	300	Corn: Time in minutes from start of test 30	60	90	120	150	180	240	300
			Inches per hour.								*Inches per hour.*							
1-B&C	June '42	Berwick	1.74	1.57	1.47	1.40	1.33	1.27	1.18	1.11	0.81	0.38	0.32	0.29	0.27	0.27	[1]0.27	[1]0.27
2-B&C	"	"	1.49	1.18	.93	.73	.57	.47	.34	.30	1.00	.50	.35	.28	.23	.21	[1].18	[1].14
7-B&C	"	"	.65	.28	.15	.08	.07	.07	[1].07	[1].07	.23	.16	.11	.08	.06	.06	[1].06	[1].06
8-B&C	"	"	.20	.19	.19	.19	.19	[1].19	[1].19	[1].19	.23	.16	.13	.12	.12	.12	[1].12	[1].12
9-B&C	Oct. '42	"	1.52	1.23	.94	.67	.40	.29	.21	[1].20	.51	.29	.29	.23	[1].22	[1].21	[1].18	[1].15
11-B&C	"	"	1.20	.72	.52	.46	.41	.37	.31	.28	.15	.11	[1].11	[1].10	[1].10	[1].09	[1].08	[1].07
18-B&C	"	"	1.59	1.48	1.41	1.30	1.13	.90	.43	[1].24	.18	.06	.03	.02	[1].02	[1].02	[1].02	[1].02
Total			8.39	6.65	5.61	4.83	4.10	3.56	2.73	2.39	3.11	1.66	1.29	1.12	1.02	.98	.91	.83
Mean			1.20	.95	.80	.69	.59	.51	.39	.34	.44	.24	.18	.16	.15	.14	.13	.12
3-B&C	June '42	Tama	[2]1.78	[2]1.78	[2]1.78	1.78	1.35	1.01	.59	.40	1.43	1.03	.76	.62	.53	.48	.42	.40
4-B&C	"	"	1.67	1.59	1.53	1.49	1.45	1.42	1.35	1.29	.34	.19	.14	.13	.13	[1].13	[1].13	[1].13
5-B&C	"	"	1.55	1.30	1.04	.69	.35	.17	.05	[1].04	1.15	.71	.53	.44	.37	.32	.25	.21
6-B&C	"	"	.53	.35	.29	.26	.24	.23	[1].22	[1].21	.44	.25	.16	.10	.09	[1].08	[1].06	[1].06
12-B&C	Oct. '42	"	1.38	1.38	1.38	1.37	1.37	1.36	1.33	1.30	.23	.11	.09	.09	[1].08	[1].08	[1].07	[1].06
13-B&C	"	"	1.03	1.00	.99	.98	.98	.98	.98	.98	.30	.21	.16	[1].13	[1].09	[1].09	[1].09	[1].09
14-B&C	"	"	.80	.88	.94	1.00	1.04	1.06	1.11	1.15	.28	.06	.01	0	0	0	0	0
Total			8.74	8.28	7.95	7.57	6.78	6.23	5.63	5.37	4.17	2.56	1.85	1.51	1.29	1.18	1.02	.95
Mean			1.25	1.18	1.14	1.08	.97	.89	.80	.77	.60	.37	.26	.22	.18	.17	.15	.14
20-B&C	June '43	Viola	1.08	.89	.71	.53	.34	[1].22	.20	[1].20	.81	.36	.24	.19	.17	[1].16	[1].16	[1].16
21-B&C	"	"	.63	.41	.36	.36	.28	[1].28	[1].28	[1].28	.58	.10	.03	.01	[1].01	[1].01	[1].01	[1].01
22-B&C	"	"	.30	.17	[1].10	[1].05	[1].03	[1].01	0	0	.82	.33	.18	.09	.06	[1].06	[1].06	[1].06
Total			2.01	1.47	1.17	.94	.65	.51	.48	.48	2.21	.79	.45	.29	.24	.23	.23	.23
Mean			.67	.49	.39	.31	.22	.17	.16	.16	.74	.26	.15	.10	.08	.08	.08	.08
23-B&C	"	Muscatine	2.90	2.34	1.83	1.63	[1]1.44	[1]1.24	[1]1.04	[1].80	.39	.14	.12	.08	[1].08	[1].08	[1].08	[1].08
24-B&C	"	"	1.00	.69	.66	.66	[1].56	[1].46	[1].46	[1].46	.87	.28	.19	.10	[1].10	[1].10	[1].10	[1].10
25-B&C	"	"	1.36	1.08	.92	.82	.75	.70	.58	[1].58	.89	.30	.23	[1].18	.15	[1].15	[1].15	[1].15
Total			5.26	4.11	3.41	3.11	2.75	2.40	2.08	1.84	2.15	.72	.54	.36	.33	.33	.33	.33
Mean			1.75	1.37	1.14	1.04	.92	.80	.69	.61	.72	.24	.18	.12	.11	.11	.11	.11
26-B&C	"	Clinton	.82	.50	.47	.30	.26	.25	.18	[1].18	1.05	.51	.34	.27	[1].27	[1].27	[1].27	[1].27
27-B&C	"	"	.92	.81	.73	.66	.61	.56	.49	.43	1.25	.38	[1].11	[1].10	[1].10	[1].10	[1].10	[1].10
28-B&C	"	"	1.56	1.11	.72	.48	.37	.33	[1].27	[1].27	1.16	.70	.53	.43	.35	.28	.17	.16
Total			3.30	2.42	1.92	1.44	1.24	1.14	.94	.88	3.46	1.59	.98	.80	.72	.65	.54	.53
Mean			1.10	.81	.64	.48	.41	.38	.31	.29	1.15	.53	.33	.27	.24	.22	.18	.18

[1]Estimated figure based on extension of curve.
[2]No runoff--infiltration not at capacity rate.

TABLE 10.--*Mass infiltration at various times from start of test--infiltrometer survey, Peoria County, Ill.*

Plot	Date	Soil	Bluegrass: Time in minutes from start of test								Corn: Time in minutes from start of test							
			30	60	90	120	150	180	240	300	30	60	90	120	150	180	240	300
			Inches								Inches							
1-B&C	June '42	Berwick	0.88	1.70	2.45	3.15	3.85	4.50	5.76	6.89	0.70	0.95	1.12	1.27	1.41	1.54	[1]1.81	[1]2.08
2-B&C	"	"	.80	1.50	2.05	2.43	2.75	3.01	3.43	3.74	.72	1.05	1.25	1.41	1.54	1.65	[1]1.83	[1]1.97
7-B&C	"	"	.60	.79	.89	.95	.99	1.02	[1]1.09	[1]1.16	.44	.54	.62	.68	.72	.76	[1].82	[1].88
8-B&C	"	"	.34	.44	.53	.63	.73	[1].83	[1]1.02	[1]1.21	.28	.37	.45	.51	.57	.63	[1].75	[1].87
9-B&C	Oct. '42	"	.84	1.59	2.17	2.56	2.78	2.95	3.20	[1]3.40	.53	.71	.85	.97	[1]1.08	[1]1.18	[1]1.37	[1]1.53
11-B&C	"	"	.74	1.22	1.51	1.75	1.97	2.18	2.53	2.81	.24	.30	[1].35	[1].40	[1].45	[1].49	[1].57	[1].64
18-B&C	"	"	.82	1.58	2.10	2.82	3.48	4.05	4.77	[1]5.13	.33	.38	.41	.42	[1].43	[1].44	[1].46	[1].48
Total			5.02	8.82	11.70	14.29	16.55	18.54	21.80	24.34	3.24	4.30	5.05	5.66	6.20	6.69	7.61	8.45
Mean			.72	1.26	1.67	2.04	2.36	2.65	3.11	3.48	.46	.61	.72	.81	.89	.96	1.09	1.21
3-B&C	June '42	Tama	[2].89	[2]1.78	[2]2.67	3.49	4.26	4.91	5.80	6.32	.85	1.48	1.92	2.26	2.55	2.62	3.30	3.74
4-B&C	"	"	.84	1.65	2.43	3.20	3.93	4.65	6.05	7.40	.36	.49	.58	.65	.72	[1].78	[1].91	[1]1.04
5-B&C	"	"	.80	1.56	2.14	2.55	2.80	2.93	3.02	[1]3.06	.75	1.23	1.53	1.77	1.98	2.16	2.45	2.69
6-B&C	"	"	.43	.63	.79	.93	1.05	1.17	[1]1.39	[1]1.60	.45	.61	.71	.78	.82	[1].86	[1].94	[1]1.00
12-B&C	Oct. '42	"	.70	1.38	2.06	2.76	3.47	4.16	5.49	6.80	.40	.48	.53	.57	[1].61	[1].65	[1].72	[1].78
13-B&C	"	"	.54	1.04	1.54	2.04	2.53	3.02	4.00	4.98	.35	.47	.56	[1].64	[1].69	[1].73	[1].82	[1].91
14-B&C	"	"	.37	.81	1.28	1.74	2.26	2.79	3.88	5.03	.35	.42	.44	.44	[1].44	[1].44	[1].44	[1].44
Total			4.57	8.85	12.91	16.71	20.30	23.63	29.63	35.19	3.51	5.18	6.27	7.11	7.81	8.44	9.58	10.60
Mean			.65	1.26	1.84	2.39	2.90	3.38	4.23	5.03	.50	.74	.90	1.02	1.12	1.21	1.37	1.51
20-B&C	June '43	Viola	.56	1.06	1.48	1.80	1.99	[1]2.11	[1]2.31	[1]2.51	.70	.96	1.10	1.21	1.29	[1]1.37	[1]1.53	[1]1.69
21-B&C	"	"	.43	.67	.87	1.05	[1]1.21	[1]1.35	[1]1.63	[1]1.91	.63	.76	.79	[1].80	[1].81	[1].82	[1].83	[1].84
22-B&C	"	"	.26	.37	[1].44	[1].46	[1].47	[1].48	[1].48	[1].48	.71	.95	1.07	1.14	[1]1.17	[1]1.20	[1]1.26	[1]1.32
Total			1.25	2.10	2.79	3.31	3.67	3.94	4.42	4.90	2.04	2.67	2.96	3.15	3.27	3.39	3.62	3.85
Mean			.42	.70	.93	1.10	1.22	1.31	1.47	1.63	.68	.89	.99	1.05	1.09	1.13	1.21	1.28
23-B&C	"	Muscatine	1.58	2.88	3.90	4.76	[1]5.54	[1]6.21	[1]7.35	[1]8.29	.51	.61	.68	[1].72	[1].76	[1].80	[1].88	[1].96
24-B&C	"	"	.77	1.15	1.50	1.84	[1]2.20	[1]2.43	[1]2.89	[1]3.35	.75	.98	1.09	[1]1.16	[1]1.21	[1]1.26	[1]1.36	[1]1.46
25-B&C	"	"	.97	1.57	2.09	2.51	2.89	3.28	[1]3.90	[1]4.49	.61	.93	1.05	[1]1.15	[1]1.23	[1]1.30	[1]1.45	[1]1.60
Total			3.32	5.60	7.49	9.11	10.63	11.92	14.14	16.13	1.87	2.52	2.82	3.03	3.20	3.36	3.69	4.02
Mean			1.11	1.87	2.50	3.04	3.54	3.97	4.71	5.38	.62	.84	.94	1.01	1.07	1.12	1.23	1.34
26-B&C	"	Clinton	.55	.87	1.08	1.25	1.39	1.52	[1]1.70	[1]1.88	.76	1.14	1.34	1.49	[1]1.62	[1]1.75	[1]2.01	[1]2.27
27-B&C	"	"	.50	.92	1.29	1.62	1.95	2.26	2.82	3.23	.84	1.29	[1]1.37	[1]1.43	[1]1.50	[1]1.55	[1]1.66	[1]1.77
28-B&C	"	"	.85	1.54	1.99	2.28	2.48	2.66	[1]2.93	[1]3.20	.70	1.16	1.45	1.70	1.90	2.05	2.28	[1]2.48
Total			1.90	3.33	4.36	5.15	5.82	6.44	7.45	8.31	2.30	3.59	4.16	4.62	5.02	5.35	5.95	6.52
Mean			.63	1.11	1.45	1.72	1.94	2.15	2.48	2.77	.77	1.20	1.39	1.54	1.67	1.78	1.98	2.17

[1]Estimated figure based on extension of curve.
[2]No runoff--infiltration not at capacity rate.

TOPOGRAPHIC MAPS OF WATERSHEDS OF BERWICK SOIL TYPE

U.S.D.A., S.C.S., Elmwood, Ill.

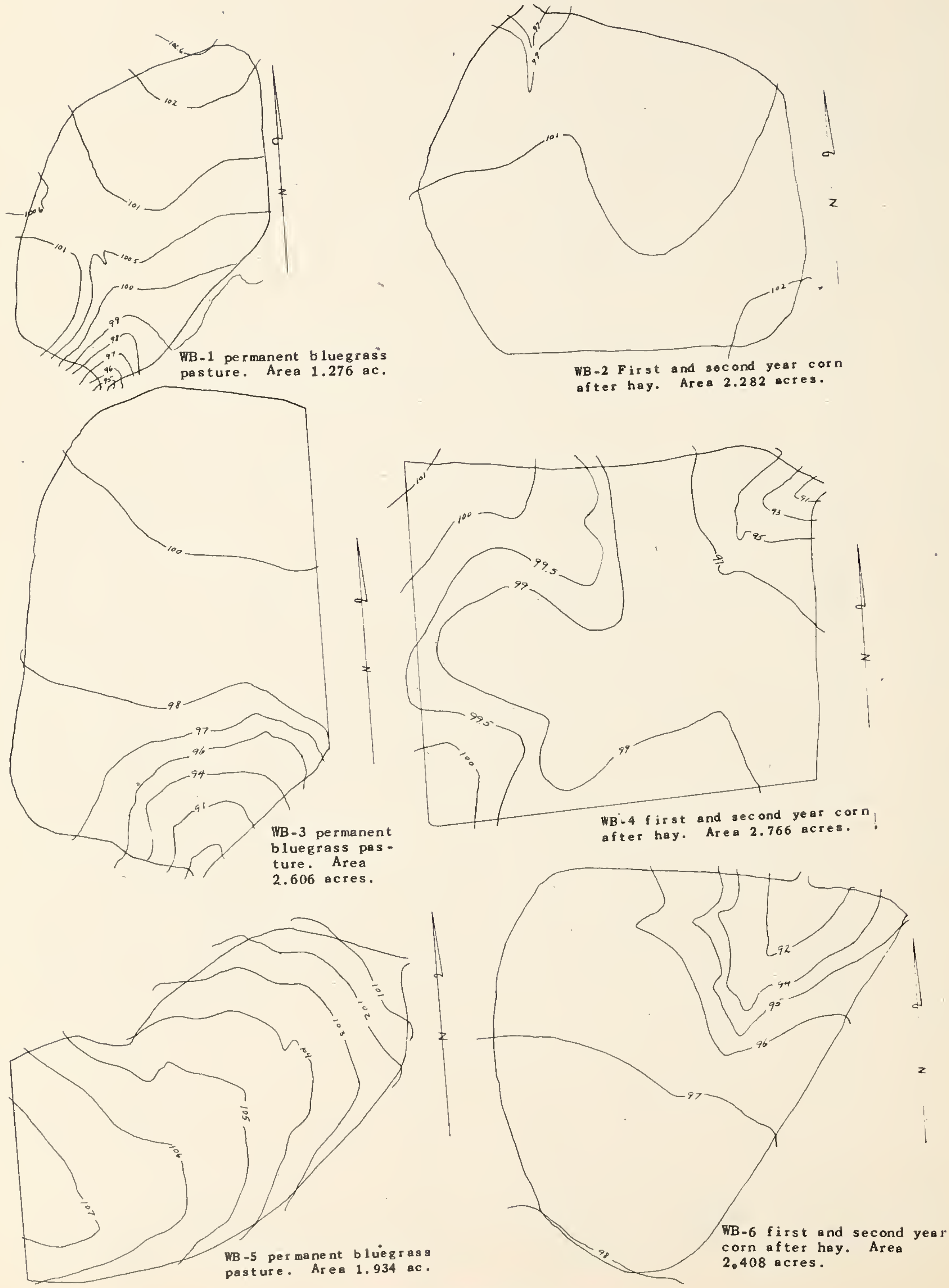


FIGURE 12.--Topographic maps of Berwick soil watersheds.

TOPOGRAPHIC MAPS OF WATERSHEDS OF TAMA SOIL TYPE
U.S.D.A., S.C.S., Elmwood, Ill.

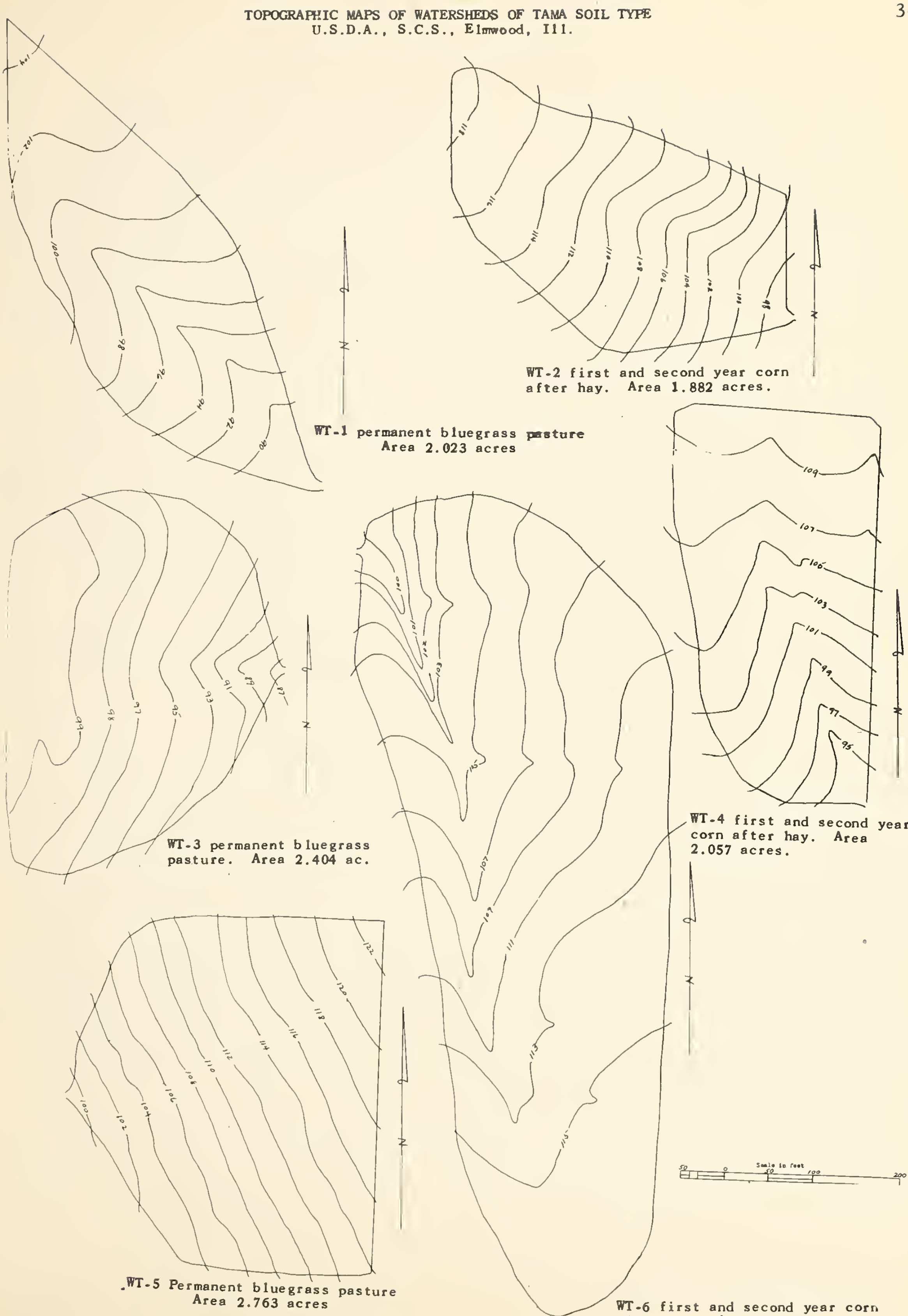


FIGURE 13.--Topographic maps of Tama soil watersheds.

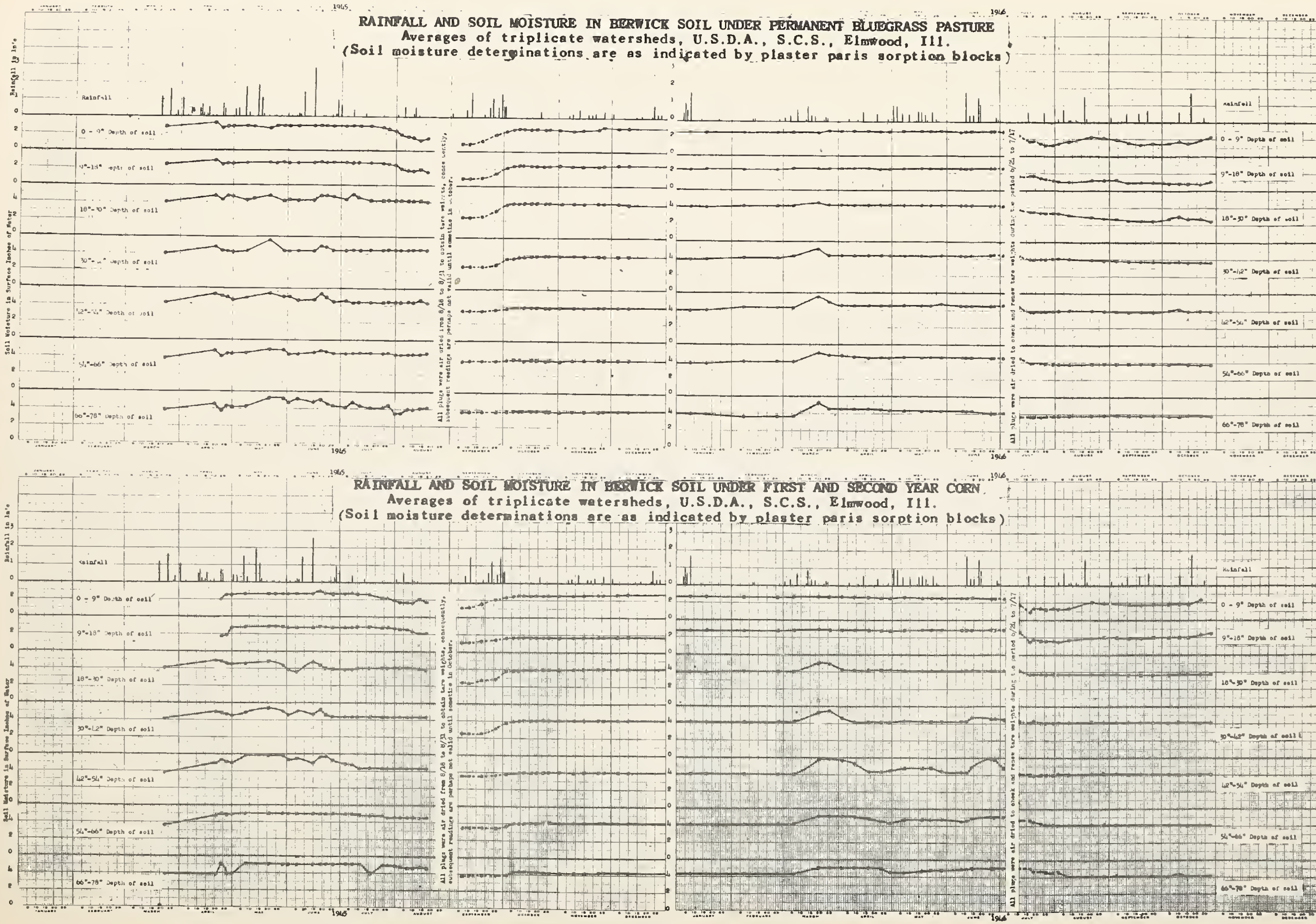
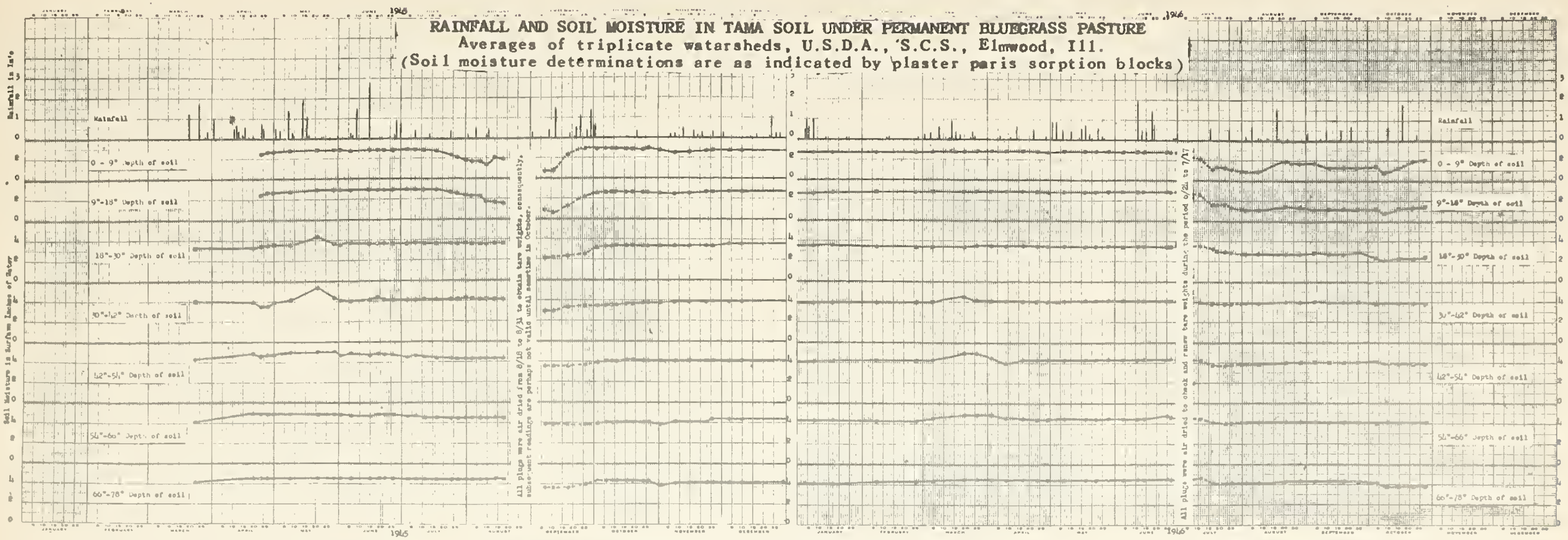


FIGURE 14.--Rainfall and soil moisture in the Berwick soil under bluegrass and corn.



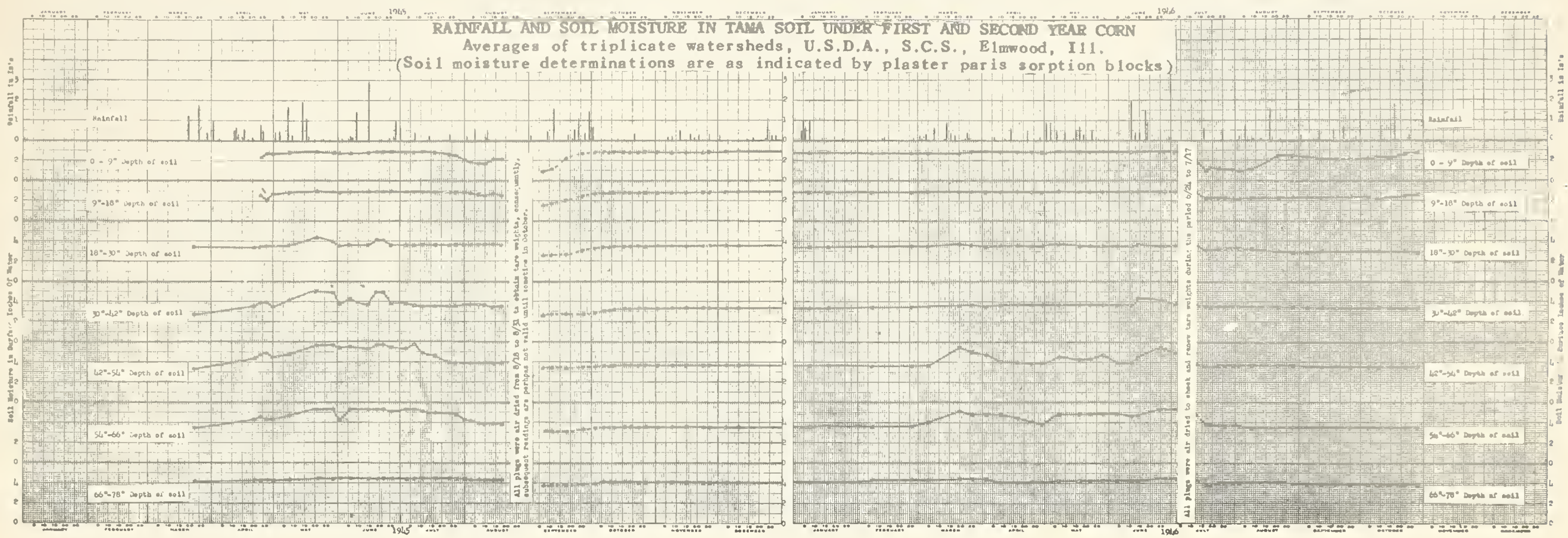


FIGURE 15.--Rainfall and soil moisture in the Tama soil under bluegrass and corn.